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ABSTRACT

A consortium of representatives of 28 states and territories prepared a set of general guidelines and principles for implementation of the metric system. Twenty-three recommendations were made in three broad areas: development and evaluation of instructional material and pedagogy (11), implementation of changeover and promotion of public support (7), and pre-service and in-service teacher education (5). In addition to these recommendations, this report provides lists of topics and activities related to the metric system appropriate to classes at different grade levels and curricular areas. A discussion of the mass-weight controversy, and a copy of the 1974 congressional amendments concerning the use of the metric system of measurement are also included. (SD)

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Interstate Consortium on Metric Education

Final Report

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CALIFORNIA STATE DEPARTMENT OF EDUCATION
Wilson Riles—Superintendent of Public Instruction
Sacramento, 1975

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Foreword

It is a small world! And people who do not use metric measurement live in an even smaller world, which is shrinking rapidly. When today's elementary children finish high school, that world will be almost completely metric. Our responsibility is clear: Every child must know the metric system.

Do we continue to train children in the archaic system? Do we continue to explain that 12 inches is one foot, that a thirteen-sixteenths wrench is slightly larger than a three-quarters wrench, or that four cups of water make six cups of coffee? The answers are coming in: "No!" say all other English-speaking countries. "No!" say the manufacturers and the man in the street. "No!" say the representatives to the Interstate Consortium on Metric Education and the teacher in the classroom. Few benefit from continuing to use two systems of measurement.

Some may complain that they need time to become familiar with metrics, but the metric system is much easier to learn than the old system. For most people, there is no reason to convert a metric measure to its equivalent in the old system. The ability to "think metric" will come easier with exclusive use of metrics.

I heartily endorse the recommendations contained in this report of the Interstate Consortium on Metric Education, and I thank the members of the consortium for their dedicated work. With their help and the help of California's educational community, I am certain we will make an early and efficient transition to the metric world.

Superintendent of Public Instruction

Preface

The Interstate Consortium on Metric Education (ICME) consisted of 28 states and territories which met in 1974 for the purpose of planning how the nation's educational institutions can best prepare Americans to understand and use metrics. The ICME was conducted with the support of the United States government through the Elementary and Secondary Education Act, Title V.

The states and territories selected for participation in the ICME were those that have centralized curriculum adoption. The chief educational officers of the participating states and territories chose as their ICME representatives those persons who had the primary responsibilities for developing metric programs for the schools in their states. Thereby, the composition of the ICME membership will maximize the impact of the ICME on the future development of instructional materials.

The state and territorial representatives who participated in the proceedings of the ICME were the following:

Lloyd M. Crook, *Alabama*
Susan M. Swan, *American Samoa*
Buel N. Bowlan, *Arizona*
Dean Whiteside, *Arkansas*
Marvin L. Sohns, *California*
Emma Lewis, *District of Columbia*
Renee Henry, *Florida*
Clare F. Nesmith, *Georgia*
Leroy J. Hirst, *Guam*
Mildred Shimizu, *Hawaii*
Richard Kay, *Idaho*
Richard E. Wiley, *Indiana*
Frank Howard, *Kentucky*
Elton L. Womack, *Louisiana*
Mississippi, James J. Hancock
Nevada, Ron Gutzman
New Mexico, B. K. Graham
North Carolina, Robert L. Jones
North Dakota, George Fors
Oklahoma, Joe Bob Weaver
Oregon, Ray Theiss
Puerto Rico, Lucia Rodriguez de Tirado
South Carolina, William B. Hynds
Tennessee, James Oakes
Texas, Marvin Veselka
Utah, Donald Clark
Virginia, E. L. Edwards
West Virginia, Richard Wilkes

The ICME participating states plus all other states were invited to send observers to the meetings of the ICME. The following persons represented their states in that capacity:

Russell Boyd, *Kentucky*
Judy Bauer, *Michigan*
Don Fineran, *Oregon*
Oregon, Ralph Little
South Dakota, Robert Travis
Washington, Eldon B. Egbers

The ICME proceedings took place in San Mateo, California, during July 21 through 25 and September 29 through October 3, 1974. Included in the proceedings were the appearances of guest speakers from educational associations, metrics organizations, governmental agencies, and public-interest groups. The contributions of the speakers were immeasurable in helping the participants to develop recommendations concerning the role of the educational community in the change to metrics.

Attending as special consultants to the ICME were Robert Hopkins, Editor of the *American Metric Journal;* Jeff Odom, Chief of the Metric Information Office of the National Bureau of Standards; Louis Sokol, President of the Metric Association; and Jack Wilson, President of the California Metric Committee. These gentlemen provided the technical expertise and assistance to ensure that the results of the ICME were technically accurate.

Planning, administering, coordinating, and reporting the ICME proceedings were accomplished by the Mathematics Education Task Force of the California State Department of Education. The Task Force consisted of Joseph Hoffmann, Delmer Lansing, Fred Lorenzen, Marvin Sohns, and Robert Tardif, manager. We are gratified by the prodigious efforts of the Task Force members, the consortium consultants, the guest speakers, Dexter Magers of the U.S. Office of Education, and the 28 consortium participants that have made the Interstate Consortium on Metric Education a truly significant step toward achieving a metric America.

WILLIAM E. WEBSTER
Deputy Superintendent
for Programs

J. WILLIAM MAY
Assistant Superintendent
for General Education

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Weights and Measures may be ranked among the necessaries of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian; to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war. The knowledge of them, as in established use, is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is riveted in the memory by the habitual application of it to the employments of men throughout life.

John Quincy Adams
Report to the Congress, 1821

Introduction to the ICME Final Report

The Interstate Consortium on Metric Education (ICME) was conceived out of the need to coordinate the many metric projects that have sprung up around the country. The most frequently occurring problem created as a result of the proliferation of such projects has been the absence of uniform guidelines for use in developing instructional materials. The transition period to metrics will be too short to permit a gradual evolution of guidelines, and without uniform guidelines the changeover to metrics will be less than smooth. In the absence of a federal mandate to establish an advisory board for guiding metrication efforts, the ICME has assumed the responsibility for studying the entire discipline and making recommendations for preparing children to enter a metric world.

Clearly, one key to success in schools lies in developing effective instructional materials for pupils and teachers, as well as in mounting a public-awareness program to support the school effort. The ICME began planning to accomplish these objectives at its first meeting, which was held July 21 through July 25, 1974. This first meeting served to generate an awareness among participants of the dimensions of their responsibilities. Also, preliminary recommendations were devised, upon which the work of the second meeting was based.

The second and final ICME meeting was held from September 29 through October 3, 1974, during which specific plans were developed for dealing with a variety of metric issues. Three committees were created at the second meeting, with each participant serving on one committee. Each committee dealt with one of the following topics:

1. Issues relating to pedagogy and to the development and evaluation of instructional materials
2. Issues pertaining to the implementation of a smooth changeover to metrics, including the promotion of awareness and acceptance by the general public

3. Measurement issues in teacher education, both preservice and inservice

Each of the committees developed recommendations in its area of concern. The recommendations were reviewed by the other committees, and changes were suggested as appropriate. Recommendations were then compiled in their final form and submitted for adoption by the ICME in general session.

When the last ICME session concluded on October 3, 1974, the votes of the membership were treated as tentative votes. The participants returned to their states and territories and presented the ICME recommendations to their respective agencies. Changes in the voting were allowed to be made up to October 18, 1974. A few changes were made, but most of the tentative votes became the final votes. (The votes of the state of Mississippi have been included, even though Mississippi did not send a representative to the ICME meetings.) Final results of the balloting are presented in Appendix A.

Twenty-eight different state-level education departments sent representatives to participate in the meetings of the ICME. A characteristic common to all of the represented states and territories was the possession of centralized textbook adoption policies. Furthermore, all of those attending the meetings were currently engaged in the development of metric programs for their home states and territories. In addition to representatives from the 28 participating states of the ICME, official observers from Michigan, South Dakota, and Washington attended ICME meetings.

The ICME staff feels that a second project should be conducted to devise an efficient plan for schools and school districts to use in the changeover to metrics. Such a project would be a worthy and logical extension of the ICME. Conceivably, the recommendations of the ICME might function as a baseline for the project. Furthermore, the states that did not participate in the ICME should also be participants in the project, which could develop models for local implementation of metric education in all states and territories.

Official ICME Recommendations

The ICME recommendations were devised as a set of general guidelines and principles to provide assistance to state education agencies and others involved in developing quality metric programs. Participants of the consortium believe that if the recommendations are followed, improved measurement instruction will result. Because considerable variation exists in the areas of responsibility and in degrees of that responsibility among state-level educational agencies, some modification of the recommendations may be necessary to meet the conditions unique to a particular state or territory. Furthermore, future federal and state legislation or other governmental actions may have an impact on some provisions of the recommendations.

The recommendations are the result of much thought and discussion on the subject of efficient transition to metrics (the International System of Units [SI]). In reducing the thinking of the ICME members to written language, there was a risk of leaving out ideas that merited expression. To minimize that risk, rationales were developed to expand the meanings and implications for each recommendation. The final recommendations can be categorized as follows:

- Development and evaluation of instructional materials; and pedagogy (*Recommendations 1–11*)
- Implementation of the changeover to metrics and promotion of public support (*Recommendations 12–18*)
- Preservice and inservice teacher-training programs in measurement (*Recommendations 19–23*)

Recommendation 1

The Interstate Consortium on Metric Education (ICME) recommends that the International System of Units (SI) be the standard units of measurement used in all instructional programs.

Rationale: The policy of viewing the International System of Units as the dominant system of measurement is presented in

Public Law 93-380, which was enacted by the U.S. Congress on August 21, 1974 (see Appendix B for a complete copy of Public Law 93-380, Section 403):

> (1) The Congress finds that–
>
> (A) the metric system of measurement is in general use in industrially developed nations and its use is increasing;
>
> (B) increased use of such metric system in the United States is inevitable, and such a metric system will become the dominant system of weights and measures in the United States; and
>
> (C) there is no existing Federal program designed to teach children to use such metric system and such a program is necessary if the American people are to adapt to the use of the metric system of weights and measures.
>
> (2) It is the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement with ease and facility as a part of the regular education program.
>
> (3) For the purposes of this section, the term "metric system of measurement" means the International System of Units as established by the General Conference of Weights and Measures in 1960 and interpreted or modified for the United States by the Secretary of Commerce.

It is recognized that the use of the Customary units will continue in the United States for an undetermined period of time and that two systems of measurement will exist in many schools during the transition to SI as the standard system of measurement. Nevertheless, special needs will place the Customary units in a different role, and, with a few exceptions, Customary units will eventually acquire a status merely of historical reference.

Recommendation 2

The ICME recommends that for matters concerning definition of units, style, and spelling that the International System of Units (SI), as stated in the U.S. Department of Commerce publication NBS 330 and the American Society for Testing and Materials publication E 380-72, be used in the preparation of instructional materials.

Rationale: To provide a sound and accurate basis for the content of metric education, a reliable source of technical information must be identified and utilized. Such a source is the National Bureau of Standards Special Publication 330 *The International System of Units (SI).* NBS 330 is an approved English language translation of the report entitled *Le Système International d'Unités,* which was originally issued by the International Bureau

of Weights and Measures established under the provisions of the Treaty of the Metre in 1875 to w ich the United States was a signatory.

To be consistent in matters of style, spelling, and definition of units in instructional materials, the ICME reviewed *Metric Practice Guide*, publication E 380-72 of the American Society for Testing and Materials (ASTM), and found it acceptable for these purposes.

The ICME recognizes that at least two exceptions are commonly made to the practices in the suggested guides; namely, spelling of the unit of length and the use of the word *weight* to designate both mass and force.

Although there has been no national consensus on the spelling of the base unit of length, the ICME prefers the spelling *metre*. Additionally, the preferred spelling for the unit of capacity is *litre*.

In common practice, the word *weight* means either mass or force. The ICME prefers that the word *weight* and its derivatives (weigh, weighing, and so forth) be avoided in instructional programs. Units of mass, such as the kilogram, should be used whenever mass is intended; units of force, such as the newton, should be used whenever force is intended (refer to pages 17 through 19 for a more complete explanation of *weight-mass*).

Recommendation 3

The ICME recommends that during the period of transition from the U.S. Customary system of measurement to the metric system of measurement that provision be made for the inclusion of metric materials commensurate with the achievement and maturity of the students. The scope should be sufficiently broad and sequenced in a manner to facilitate student development to a level of performance normally expected at appropriate (various) maturity levels.

Rationale: The ICME recognizes that it may be advisable during the transition period from the U.S. Customary system to the International System of Units for students at the various grade levels first to be exposed to the rudiments of the SI system and later encouraged to develop their concepts in metric measurement. It is essential that the material developed for this purpose be at the appropriate maturity level so as to elicit the proper student response and to enable an orderly transition to metrics.

Recommendation 4

The ICME recommends that instructional materials, to reflect a genuine concern for how and when children learn to measure, follow an appropriate sequence: (a) comparison between objects; (b) comparing nonstandard units with objects; (c) comparing objects to be measured with SI units; (d) choosing measurement units of appropriate size for specific tasks.

Rationale: All measures are based on the idea of making a comparison. Comparisons are made between what is to be measured and a reference object.

Recommendation 5

The ICME recommends that activity oriented measurement experiences for children be planned to include the following learning processes: language development, estimation and verification, simple matching and comparison, ordering, simple relations and mapping, and pictorial representations.

Rationale: Certain processes have been identified as being important to a child's intellectual development. These processes include matching (many-to-one and one-to-one correspondence), ordering (putting things in serial order), and forming relations. Also, children must be able to communicate their experiences. Communication occurs when children are able to translate their experiences into pictorial or abstract terms.

Recommendation 6

The ICME recommends that all prefixes in the range milli- to kilo- be presented to illustrate the logical structure of the metric system. However, commonly used units should be emphasized in learning activities and applications and are in boldface print below:

millimetre	***millilitre***	***milligram***
centimetre	*centilitre*	*centigram*
decimetre	*decilitre*	*decigram*
metre	***litre***	***gram***
dekametre	*dekalitre*	*dekagram*
hectometre	*hectolitre*	*hectogram*
kilometre	***kilolitre***	***kilogram***

Two commonly used terms which do not incorporate commonly used prefixes are "cubic decimetre" (dm^3) and "hectare" (ha). The cubic decimetre should be used to show the relationship

between linear measure and volume; the square kilometre and/or the hectare are used as the units for large land areas.

Rationale: The International System of Units (SI) includes many units of a highly technical nature. In fact, the majority of SI units are intended for use in specialized areas of endeavor and will not be of direct concern to the general public. The "commonly used" units listed in *Recommendation 6* are those that all persons should know and/or be able to use efficiently. However, all of the prefixes presented in NBS 330 and ASTM E 380-72 should be used when appropriate. Square kilometres should be used when square miles are applicable; hectares should be used when acres are applicable.

Recommendation 7

The ICME recommends that the recording of measurements within SI be accomplished in decimal notation.

Rationale: Because of its nature, the metric measurement system is related to the base-ten place value system. By utilizing base-ten experiences, it becomes logical to record metric measurement in decimal notation. Attention can be given to developing decimal competencies early in the learning sequences.

Recommendation 8

The ICME recommends that the conversion process between the International System of Units (SI) and other systems of units be avoided. In disciplines in which conversion is presently relevant and required, appropriate information should be made available so that the use of conversion formulas will not be required.

Rationale: There is little need for conversion exercises between measurement systems even though informal comparisons between the metric system and the U.S. Customary system may occasionally be desirable. However, conversions within the metric system should be taught, with emphasis on the learner's understanding of the relationship among metric units as revealed by the base-ten nature of the metric system.

Recommendation 9

The ICME recommends that in the pronunciation of metric prefixes the accent be placed on the first syllable.

Rationale: For purposes of the clarification in the pronunciation of the vocabulary associated with the International System of Units (SI), the recommendation indicates that voice stress be placed on the first syllable of words generated when prefixes are added to the names of units to form multiples or submultiples of the units.

Recommendation 10

The ICME recommends that effort be made to ensure that metrication be realized through integration of the International System of Units (SI) throughout the school curriculum and that the metric system not be presented as an isolated topic of study.

Rationale: It is dangerous to the educational process when any curricular strand or subcomponent of a strand is singled out of context for special emphasis. If so treated, metrics could easily become identified as a special or limited subject. It is the intent of this recommendation that metrics *not* be identified as a special subject.

Recommendation 11

The ICME recommends that evaluative criteria for the adoption of instructional materials include the pertinent recommendations of the consortium.

Rationale: Evaluation processes may vary from place to place, but as it relates to measurement, the evaluation criteria to be used should have a common core. Additional criteria, such as cost or format, may be included according to local needs.

Recommendation 12

The ICME recommends that metric-awareness programs for the public and intensive inservice programs for school personnel precede adoption of metric educational materials.

Rationale: Past experience indicates the necessity of providing information to the public prior to introducing new programs in the classroom.

Recommendation 13

The ICME recommends that state educational agencies encourage teacher-education institutions to begin immediately to include opportunities for students to develop competencies in using and teaching the metric system.

Rationale: Since public schools are rapidly approaching the introduction of the metric system, teacher-education institutions should include the study of the metric system in their programs.

Recommendation 14

The ICME recommends that by January 1, 1978, state educational agencies include in their evaluative criteria for adoption of instructional materials the pertinent recommendations of this report.

Rationale: See rationale for *Recommendation 11.*

Recommendation 15

The ICME recommends that during the adoption cycle of the transition period that state educational agencies encourage local educational agencies to provide instructional materials to supplement textbooks that have little or no metric measurement content.

Rationale: Until the metric system is the predominant system in instructional materials, local educational agencies should secure supplements to provide adequate metric instruction.

Recommendation 16

The ICME recommends that January 1, 1980, be the target date for the completion of the transition to the metric system in textbooks and other instructional materials; the ICME recognizes that certain vocational/technical timelines may be bound to related industrial conversion.

Rationale: By 1980, each state will have completed at least one adoption cycle.

Recommendation 17

The ICME recommends that coordinated state efforts be made to inform and involve business, industry, and other organizations in the transition to SI metrics. A broad, multifaceted public-awareness program should be undertaken and should include but not be limited to the following:

- *Publication of metric information in state-agency, teacher-association, and other professional journals and publications*
- *Inclusion of metric sessions in the meetings of professional organizations*

- *Encouragement of television stations to present programs and public-service announcements about the metric system*
- *Encouragement of libraries and instructional-material centers within the state to obtain metric related materials*
- *Establishment of communication channels to provide information about the metric system and assistance to local educational agencies in implementing public relations programs in metric education*
- *Encouragement of and assistance to local educational agencies in efforts to inform and involve parents in the transition to the metric system*

Rationale: An exhaustive list of possible activities in public awareness is impossible. The extent of the efforts of any state must be tempered by the resources available, the reaction of the public through surveys, and feedback from past information efforts.

Recommendation 18

The ICME recommends that state educational agencies encourage formative evaluation to determine proper placement for metric measurement activities.

Rationale: Continuous formative evaluation with effective feedback systems is required for all positive changes in materials.

Recommendation 19

The ICME recommends that preservice and/or inservice education programs be designed to prepare elementary teachers, administrators, and support personnel involved in instruction to implement measurement using metric units. The recommended program includes two areas of concern: (a) metric awareness; and (b) metric measurement experiences for teachers and aides.

Rationale: The rationale for *Recommendation 19* is presented in detail on pages 13 through 16.

Recommendation 20

The ICME recommends that preservice and/or inservice training programs for teachers at the secondary school level (grades seven through twelve) be designed to help these teachers become aware of the basic content and learning principles used in the elementary metric programs. In addition, secondary training programs should contain more concentrated, in-depth treatment of measurement

for teachers in specialized areas. These specialized areas are: (a) vocational/technical education, including industrial arts, home economics, and related fields; and (b) mathematics and science.

Rationale: The rationale for *Recommendation 20* is presented in detail on pages 13 through 16.

Recommendation 21

The ICME recommends that state educational agencies provide leadership by developing a core of resource personnel whose responsibility will be to implement metric education programs at the local level.

Rationale: The need for implementing a variety of metric education programs at the local level necessitates the training of resource personnel who can carry out these programs effectively. A core of resource personnel could be trained and then in turn train others to assist in implementing metric education programs all the way to the local school level.

Recommendation 22

The ICME recommends that measurement inservice programs for individuals directly involved in teaching measurement to students be of 10 to 16 hours duration. Introductory inservice programs of 3 to 6 hours duration on metric measurement should be designed for all individuals involved in instruction. In both programs, "hands-on" activities should be emphasized.

Rationale: This recommendation is needed to identify the amounts of time that are adequate for the accomplishment of the objectives for the various types of preservice and inservice programs.

Recommendation 23

The ICME recommends that (a) mathematics and science teachers assume the major responsibility for teaching the metric system; and (b) teachers in all subject areas assume the responsibility for teaching applications of the metric system.

Rationale: Teaching the metric system is a multidisciplinary concern.

Suggestions for Teacher Inservice Training

In addition to its official recommendations, the ICME developed suggestions concerning the implementation of preservice and inservice teacher-training programs at the elementary and secondary school levels. Two areas of concern that were identified regarding both the elementary and the secondary level programs were (1) metric awareness programs; and (2) experiences with metric measurement for teachers and aides.

Inservice Training for Elementary Teachers

To fulfill the intent of the elementary school preservice and inservice recommendation (*Recommendation 19*), the ICME suggests that the following components be incorporated in metric awareness programs:

1. *History*—A brief historical background on measurement should be presented that includes progress made in the implementation of SI metrics at the local, state, national, and international levels.
2. *Advantages of the SI metric system*—The advantages of SI metrics that teachers should be aware of include (a) SI metrics is based on decimal numeration similar to the U.S. monetary system, and the SI system is therefore easy to understand and use; and (b) the coherence and simplicity of SI metrics are factors that have contributed to its official acceptance by approximately 90 percent of the world's population.
3. *Resistance to changing to SI metrics*—Teachers should be prepared to expect some natural resistance to the acceptance of the SI metric system and should be able to cope with this resistance in a positive manner.
4. *Introduction to SI metric units*—Teachers should have the opportunity to use common SI metric units, such as by holding a kilogram mass.

The ICME suggests that experiences with metric measurement for elementary level teachers and aides include the following:

1. Activities similar to those in which students will be involved. The activities should range from free exploration with a variety of materials to such structured exercises as the following:
   a. Measurement activities directly related to real world situations
   b. Construction and use of simple measurement devices
   c. Games, puzzles, and problems to develop and reinforce the basic concepts and skills of measurement and to achieve proficiency in conversion techniques within the metric system
2. Informal and formal diagnostic techniques that enable the teacher to determine the level of conceptual and skill readiness of students
3. Experiences that enable teachers to acquire a knowledge of the prefixes, symbols, and notation terminology used in SI metrics
4. Experiences that enable teachers to use a variety of community resources
5. Opportunities to examine a variety of learning materials for measurement

Inservice Training for Secondary Teachers

To fulfill the intent of the secondary school preservice and inservice recommendation (*Recommendation 20*), the ICME suggests that the following metric subjects be treated in metric-awareness programs:

For all teachers in grades seven through twelve

Historical background
Legal status (federal, state, and local)
Implications of metric implementation (national economy, education, and consumer)
Familiarity with units of length, mass/weight, time, temperature, volume/capacity, and speed
Decimal system of numeration (similarity to U.S. monetary system)
Metric prefixes and symbols
Issues and concerns

For vocational/technical teachers

Familiarity with essential metric units, prefixes, and symbols
Industrial uses
Mass-weight clarification
Other skills needed for specific subjects
Funding opportunities

For mathematics and science teachers

Technical definitions of base units
Derived and supplemental units
Scientific notation

The ICME suggests that experiences with metric measurement for teachers and aides include the following topics:

For all teachers in grades seven through twelve

Personal measurements
Estimations and verifications
Error in measurement and approximation
Travel distances
Selection of appropriate units
Construction and calibration of measuring instruments
Practice with measuring
Conversion within metric system
Unit pricing practices
Criteria for selection of instructional materials

For vocational/technical teachers

Vernier scales
Metric (radial) protractors
Map and scale drawing skills
Mensuration formulas
Instruments used in specific courses
Visitation of exemplary programs

For vocational/technical teachers at the senior high school level only

More sophisticated instruments
Conversion skills needed for specific courses

For mathematics and science teachers

Very small and very large units of measurement
Application of time units
Factor label/unit analysis
Map and scale drawing skills
Mensuration formulas

Instruments used in specific courses
Visitation of exemplary programs

For mathematics and science teachers at the senior high school level only

Derived units as needed
General physical constants
Derivation of physical formulas
More sophisticated instruments
Conversion skills needed for specific courses

The Mass-Weight Controversy

In the rationale for *Recommendation 2*, it was noted that the word *weight* is often misused. Scientifically, the term *weight* has been associated with the concept of force. However, in common practice, the term *weight* has been used to refer to the concept of mass.

In the U.S. Customary system, which is ostensibly a gravitationally based system of measurement, the unit *pound* has been defined as a mass of 0.453 923 7 kilogram. On the other hand, the SI system is an absolute system. While it might be useful to explicate the differences between an absolute system and a gravitational system, suffice it to say that in an absolute system the concepts of *mass* and *weight* are distinct and clear, as well as computationally easy; the distinctions between *mass* and *weight* in a gravitational system are not nearly as easy to perceive.

It is unfortunate that the term *weight* has been defined as a force. In light of current practice, it would have been better originally to define *weight* as synonymous with *mass*. The confusion or misuse of the term *weight* is an artifact of shifting from a gravitational to an absolute system of measurement.

In resolving the problems regarding use of the terms *mass* and *weight*, three possible solutions exist:

1. Use the word *mass* to refer to kilograms and avoid using the words *weight* and *weigh*.
2. Redefine the word *weight* to mean "mass"; and redefine the word *weigh* to mean "measure the mass of." Have scientists and others use the word *force* and not the word *weight* in referring to newtons.
3. Use the word *weight* to refer to kilograms and to newtons, the measurement unit for *force*. The measurement units used will serve to inform others of the meaning of the term *weight*—a *mass*, if kilograms; a *force*, if newtons.

In resolving the problem of use or misuse of the term *weight*, the ICME has been concerned with the following:

Metrication—Recommendations regarding terminology should not impede public acceptance of metrics.

Effective teaching of pupils—Recommendations regarding terminology should complement effective teaching practices. Terminology that requires pupils to unlearn meanings at a later point in their studies should be avoided. Difficult concepts should be taught only when pupils' experiences have been expanded sufficiently to allow correct conceptualization. When terminology is merely a tool of communication, emphasis on technically correct terminology should follow the development of understanding.

Interagency communication—Recommendations regarding terminology should facilitate communication among scientific, educational, governmental, private, and corporate agencies functioning in our economy. The changeover to the metric system will serve as an economic stimulus characterized by increased efficiency at home and in the international marketplace—but only if communication is clear.

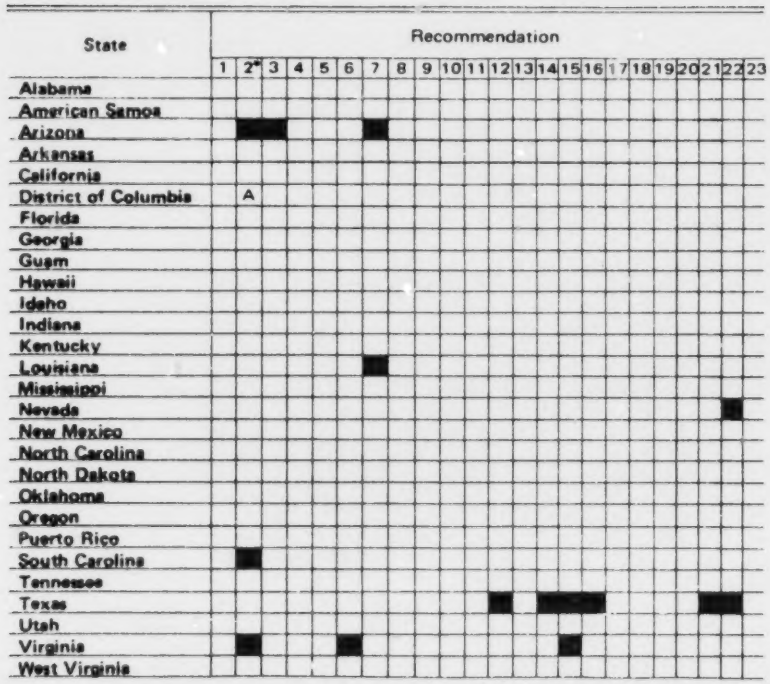
The adoption of SI metrics requires a major linguistic change in the method of referring to the amount of matter in an object. Instead of a unit of measure of the gravitational force on an object, a unit of measure of the quantity of matter is used in the SI system.

In short, there is no ambiguity of terms in SI metrics: the kilogram is a unit of *mass;* the newton, a unit of *force.* The kilogram is one of the seven base units of the SI system and cannot be confused with the newton, which is a unit of force that is derived from three base units (kilogram, metre, and second).

During the changeover to a metric standard, many new terms can be expected to arise, not only for *weight* and *mass* but also for length, volume, temperature, and others. If all the areas of change are identified and explained at one time, the problem of public acceptance of correct *weight* and *mass* terminology will be considerably easier to solve. If the term *weight* continues to be used ambiguously, then the public cannot be expected to value the changeover to SI. Therefore, the ICME has chosen the first alternative above and recommends not using the term *weight* to refer to *mass.* (Skeptics insist that the public cannot make the adjustment to using new terminology. Those skeptics underestimate the intelligence of our citizens and probably do not realize the importance of the problem.)

To summarize, it is clear that in day-to-day commerce the general public is interested in the measurement of *mass*, not *force*. Transactions are made on the quantity of matter being sold and not the *force* by which the Earth attracts the body being measured. (This is not an idle concern since the gravitational force has been found to vary by as much as 0.5 percent at different locations on the planet's surface.) Even though Homo sapiens may use measurement tools that measure *force*, the tools are designed and calibrated to translate *force* into units of *mass*. While an object may impart different forces on scales in different locations, the measurements registered in kilograms will be essentially constant; i.e., measurements of *mass*.

Appendix A
Final Voting on ICME Recommendations



KEY TO VOTING
■ No
□ Yes
Ⓐ Abstention

*Two of the three votes cast against *Recommendation 2* reflected the concern of those participants (Arizona and Virginia) about the legality in their respective states of recommending a commercial publication (ASTM publication E 380-72) for use as a guide in preparing instructional materials. The third "no" vote (South Carolina) was cast because the state considered the weight-mass issue received too little discussion in the rationale.

Appendix B

Education Amendments of 1974
U.S. Public Law 93-380, Title IV, Section 403

EDUCATION FOR THE USE OF THE METRIC SYSTEM OF MEASUREMENT

Sec. 403. (a) (1) The Congress finds that–

(A) the metric system of measurement is in general use in industrially developed nations and its use is increasing;

(B) increased use of such metric system in the United States is inevitable, and such a metric system will become the dominant system of weights and measures in the United States; and

(C) there is no existing Federal program designed to teach children to use such metric system and such a program is necessary if the American people are to adapt to the use of the metric system of weights and measures.

(2) It is the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement with ease and facility as a part of the regular education program.

(3) For the purposes of this section, the term "metric system of measurement" means the International System of Units as established by the General Conference of Weights and Measures in 1960 and interpreted or modified for the United States by the Secretary of Commerce.

(b) (1) The Commissioner shall carry out a program of grants and contracts in order to encourage educational agencies and institutions to prepare students to use the metric system of measurement.

(2) The Commissioner is authorized to make grants to, and contracts with, institutions of higher education, State and local educational agencies, and other public and private nonprofit agencies, organizations, and institutions to develop and carry out the policy set forth in subsection (a).

(c) (1) Financial assistance under this section may be made available only upon application to the Commissioner. Any such application shall be submitted at such time, in such form, and containing such information as the Commissioner shall prescribe by regulation and shall be approved only if it–

(A) provides that the activities and services for which assistance is sought will be administered by, or under the supervision of, the applicant;

(B) describes a program which holds promise of making a substantial contribution toward attaining the purposes of this section;

(C) sets forth such policies and procedures as will insure adequate evaluation of the activities intended to be carried out under the application; and

(D) contains such other provisions as the Commissioner determines necessary in order to accomplish the purposes of this title.

(2) An application from a local educational agency under this section may be approved only if the State educational agency of the State in which such local agency is located has been notified of the application and has been given a reasonable opportunity to offer recommendations with respect to the approval thereof.

(d) For the purpose of carrying out this section, the Commissioner is authorized to expend $10,000,000 for each of the fiscal years ending prior to July 1, 1978.

74-126 DE 7591 3-75 1M